Treatment of ADS Spent Liquid Metal Target as a Waste Form

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Goal and Scope. In 1998 the development of the pilot target circuit (TC-1) of the 1 MW power accelerator-driven system (ADS) with a liquid lead-bismuth target (LBT) has been started at IPPE. The TC-1 is the main part of the ADS to be created at the US Los Alamos National Laboratory using the LANSCE proton accelerator infrastructure. It is intended for experimental study and validation of the capabilities of lead-bismuth coolant (LBC) for use as neutron producing target as a part of multi-functional ADS, including that for nuclear waste transmutation. The TC-1 represents a complicated engineering facility, consisting of the following main components: target; heat exchanger; electric-magnetic pump; drainage tank; compensation volume; radiation shielding; control and protection system; electric heating system; supporting metal structures and other units. It is assumed there will be no repair work on the TC-1 after the 6 months on-beam post irradiation study. Thus, after decommissioning it should be removed from the testing site and placed into a repository. The purpose of this work was to analyze the radiation parameters of TC-1 and formulate the problems of its management as a waste form.

Methods. Using the LANSCE accelerator conditions (proton energy ~800 MeV, current ~1.25 mA, irradiation operation ~6 months), the different radiation parameters of the TC-1 were determined. Among the main mediums that are of radiation danger during and after the TC-1 lifetime are the radioactive LBC, cover protection gas, container air and cooling water in the TC-1 systems.

Results and Conclusions. Total specific activity of the LBC (without accounting the gaseous and volatile nuclides leakage) at the end of TC-1 lifetime is as much as 2.9×10^{13} Bq/kg. Total radioactivity and radiotoxicity of irradiated LBC were also calculated. The gaseous and volatile nuclides, which are partially transferring from the LBC surface into protection gas system (helium), are the most dangerous. Among them there are krypton, xenon, polonium, mercury, cesium, iodine, bromine, and rubidium. Radioactivity of TC-1 container air was calculated assuming that air leakage into the ventilation system is as much as ~1% per day. Energy deposition in the LBC, structure materials and radiation shielding were calculated. Radiation damage, as well as helium, hydrogen and tritium accumulation in the structure materials induced by high-energy hadrons and secondary neutrons were determined for continual target irradiation operation at the nominal beam power (1 MW). Total radioactive isotope generation rate was $\sim 6.2 \times 10^{10}$ Bq/s in the target cooling water and $\sim 4.2 \times 10^{9}$ Bq/s in the heat exchanger cooling water. The radiation transport through the external concrete shielding was estimated and total volume of the external shielding was determined as ?40 cubic meters.

Recommendations and Outlook. The spent TC-1 in question is a powerful source of irradiation and should be handled as a high-level waste form. In order to provide the proper long-term storage the following key issues should be considered: a) analysis of residual heat deposition and temperature conditions while TC-1 is in storage; b) prognosis of radioecological consequences because of the processes of self-heating inside spent LBC; c) development of special filters on gas system blowing-off lines to detect the vapor and aerosol phases of mercury and other volatile nuclides.